Soilutions

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Agronomic Models for Precision Farming

Len Kryzanowski, Crop Nutrition Agronomist, Karen Cannon, Agrologist, Agronomy Unit and Tom Goddard, Soil Conservation Specialist, Conservation and Development Branch

Developing agronomic models for making soil and crop management decisions may prove critical to precision farming. Farming systems are evolving in response to economic, technological and social factors. The public is taking an increasing interest in farming practices primarily in regards to food safety and environmental concerns. Two major issues that farmers consider when looking to adopt new technology are profitability and environmental impact. In Canada, the trend over the past two decades has been reduced tillage systems (direct seeding) and increased use of fertilizers and herbicides. However, the cost savings of reduced tillage does not outweigh the added cost of crop chemicals, so profit margins have remained narrow. Labour costs are high and natural resources finite, so technology must be used to maintain competitiveness in a world market.

Fertilizer use efficiency across a field can be quite variable. In the case of nitrogen, fertilizer use efficiency can be less than 50%. Soils within farm fields are inherently variable in their ability to support crop production. Applying fertilizer to fields at uniform rates, as is currently practiced, can potentially result in a highly productive soil being under fertilized and less productive soil being over fertilized. The over-fertilization of soil results in excess fertilizer than can become an environmental concern. One way of improving fertilizer efficiency and reducing environmental problems may be to use precision farming techniques to optimize the use of soil resources and external inputs (fertilizers and pesticides) on a site specific basis. Precision farming takes advantage of rapidly evolving Global Positioning Systems (GPS) technology. GPS, together with electronic sensors and controllers are used to monitor crop response under variable inputs and landscape position.

Currently in the USA, site specific agronomic recommendations are developed by conducting intensive grid soil sampling, and then making fertilizer recommendations for each grid node. The costs involved make this practice prohibitive for small grain production in Alberta.

Another option is to use a landscape sampling procedure. Here landscape features such as hilltops (shoulders), side hills (backslopes) and bottom of hills (footslopes) are sampled and characterized. This process significantly reduces the amount of soil sampling. The use of soil/crop models that can differentiate soil types (landscapes) within a field may prove to be a cost-effective alternative.

One model that holds some potential for this application is the Environmental Policy Integrated Climate (EPIC) model. EPIC was first designed to study the relationship between soil erosion and crop productivity in the United States. The model is composed of simulation components for weather, hydrology, nutrient cycling, pesticide fate, soil temperature, tillage, crop growth, crop and soil management, and economics. In an earlier study done in 1993 by AAFRD, EPIC performed well when tested against existing nitrogen response trials in southern Alberta. EPIC's promising performance in that study prompted the search for other opportunities to test EPIC on a sub field scale.

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This Issue

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

A project was initiated using EPIC to study the development of optimum agronomic management on a site specific basis. The study was further aided by the development of prototype software to integrate the EPIC model with a geographic information system. This allows the user to perform multiple runs of the EPIC model in a landscape basis with a goal of providing agronomic recommendations and risk assessment on a site specific basis across a field.

Four farmer cooperators were selected in eastern Alberta. One test field was selected on each farm. At each site, several locations representing various landscape features (shoulder, backslope and footslope) were sampled and characterized for input into the EPIC model.

Crop yields, measured using a yield monitor on a combine harvester, were found to vary by slope position at all sites. Yields measured at a given field location may also be influenced by aspect, soil moisture variability and applied fertilizer. Comparison of actual crop yields and those predicted by the EPIC model indicated that they were very similar and only a few significant differences occurred.

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These results are very promising, but more work is needed to ensure the reliability of the EPIC model for predicting crop yield and other soil processes. In order for integrated crop models to be accepted, the ability to fairly represent yield potential on a site specific basis is needed. Once the reliability of the model is established, then the model can be used to predict yield potential for various portions of the field and assist with fertilizer and other management decisions. Figure 1 is an example of a predicted crop yield map for a site in south central Alberta.

A predicted fertilizer recommendation map can also be generated to guide the variable rate application of fertilizer.

The benefit of using an integrated model is that other features of the model can be used with little additional effort. Models for pesticide leaching, erosion and tillage are more likely to be used if they come as part of an agronomic model that can be used for prescription mapping and risk assessment. A reliable model could also be used to test various management practices, climatic conditions and soil conditions on crop yields and soil conservation. Considerable work is still needed but the potential use of a model for site specific farming could provide a very powerful tool for farmers and researchers.

For more information, contact Len Kryzanowski at 427-6361.

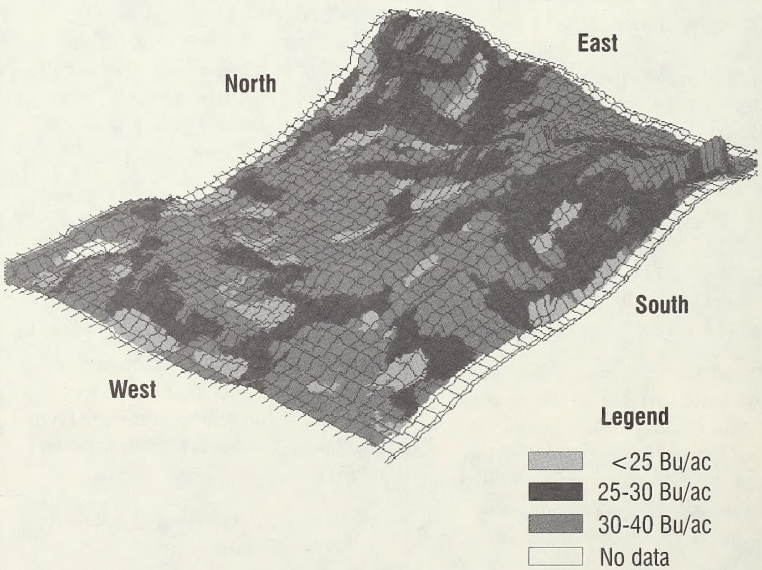

Figure 1. Predicted Spring Wheat Yield Map

Dr. Jim Robertson is retiring after 38 years with the University of Alberta.

A reception in his honor is being held on October 24, 1996. For more information, please call (403) 492-3242 or E-mail *tammy.luneng@ualberta.ca*

Herbicide Resistant Canola – Watch Those Volunteers

Linda Hall, Weed Scientist, Agronomy Unit

This year saw the successful introduction of herbicide resistant canola varieties to the prairies. These varieties allowed producers to use specific herbicides to control weeds and grow canola in fields where problem weeds previously made canola production difficult.

The switch to herbicide resistant canola varieties will require a change in management practices. Volunteer canola can be present for several years. How many years? We estimate that Argentine canola will persist in the seedbank for 2 to 3 years. Some of these seeds will germinate every year. During that time they are a weed concern that requires proper management. The volunteers will be resistant to the same herbicide as the parent plant.

Roundup Ready volunteers will be resistant to Roundup. Volunteers will not be controlled with a pre-seeding application of Roundup alone. Pursuit Smart volunteers will not be controlled by Pursuit or any other Group 2 herbicide. These are Assert, Ally, Refine, Refine Extra, Muster, Amber and Express. Fortunately, the control of these volunteers is relatively simple and inexpensive. MCPA or 2,4-D used alone or in combination with other herbicides will control these herbicide resistant volunteers.

With herbicide resistant canola varieties, record keeping becomes more critical. Because volunteers persist in the seedbank for several years, long-range herbicide planning is necessary when choosing appropriate herbicides. Roundup and Liberty are ungrouped herbicides and will play an important role in reducing the consecutive use of herbicides in Group 1 and Group 2. Weeds can quickly develop resistance to herbicides in Group 1 and 2. Pursuit is a Group 2 herbicide and producers using it should avoid using other Group 2 herbicides in the crop rotation.

Herbicide resistant crops will continue to make a significant contribution to improving weed control. However, planning crop rotations and management of resistant volunteers will require even more thought than traditional varieties.

For more information, contact Linda Hall at 427-7098.

Survival of the Fittest: Fertilizing Winter Wheat

Allan Middleton, Technologist, and Dr. Ross McKenzie, Soil Fertility Specialist, Agronomy Unit, Lethbridge

In the early 1980's, over 450,000 acres of winter wheat was grown annually in southern Alberta. But, because of drought conditions, poor fall weather and low grain prices, winter acreage dropped to less than 100,000 acres by 1990.

However, with the improved fall moisture conditions in the past few years and the release of new winter wheat varieties, there has been a renewed interest in winter wheat. AC Readymade and CDC Kestrel are new winter wheat varieties with up to a 20% yield advantage over spring wheat.

Many winter wheat growers would like to apply all their fertilizer while direct seeding in the fall, rather than broadcasting nitrogen in the following spring. But, this increases the risk of reduced emergence and winter survival. Producers needed to know if fall applied and/or seedplaced nitrogen will significantly affect plant populations, over-winter hardiness, weed competition, crop yield and quality.

In the fall of 1994, the Agronomy Unit at Lethbridge initiated a study to examine the effects of conventional vs direct seeding and fall seedplaced vs spring broadcast fertilizers on the establishment and survival of winter wheat.

Four (1994) and five (1995-1996) winter wheat sites were established in the Brown, Dark Brown and Thin Black soil zones of southern Alberta. One experiment was designed to look at fertilizer applied at the time of seeding (ammonium nitrate and urea at 0, 30, 60 and 90 kg/ha) using three openers (band, 10% seed bed utilization [SBU] and 50% SBU). The banding operation resulted in a rougher seedbed and significantly reduced emergence compared to

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direct seeding with either a hoe drill or airseeder. The higher rates of N fertilizer seedplaced with the hoe drill appeared to slightly reduce emergence at several sites. Seedplaced urea fertilizer affected emergence more so than ammonium nitrate.

Perhaps the most significant observation, so far, is that higher rates of N fertilizer, whether banded before seeding or seedplaced did not appear to have any affect on winter hardiness or overwinter survival. However, the later than normal time of seeding in the first two years of this project may be a related factor.

A second experiment studied fertilizer (ammonium nitrate and urea at 0,30, 60 and 90 kg/ha) applied in split fall and spring application vs spring only application. The 30/30 AN split tended to outperform the 60 AN spring applied treatment, while the 30/30 urea split was often poorer that the 60 U spring applied treatment.

Funding for this project was provided by Alberta Agricultural Research Institute, FFF On-Farm Demonstration Program, Viridian, Alberta Winter Wheat Producers Commission, Potash and Phosphate Institute, Westco and technical assistance from the Alberta Farm Machinery Research Centre. This project will run one more year.

Southern Alberta dryland farmers like the option of including winter wheat in their crop rotation. The benefits of growing winter wheat include:

- higher yields than spring wheat;
- spreading out the workload, resulting in better time management;
- little risk of frost damaged grain before harvest;
- reduced risk of soil erosion by wind or water during the winter and spring.

Farmers in the wetter, cooler Black and Dark Grey soils zones of the western parkland can also take advantage of these benefits. The newer varieties of winter wheat, CDC Kestrel and CDC Osprey, have sufficient winter hardiness and lodging resistance to allow expansion of the traditional winter wheat growing areas into the western parkland. However, a number of agronomic questions concerning fertilizer, weed and disease management remain unanswered for the soil, climatic, weed and disease conditions of the western parkland. To help answer these questions, the Agronomy Unit has initiated a new project with several objectives;

- To examine fall applied N with respect to source, rate and placement and it's effect on overwinter survival, yield and quality.
- To expand on existing information on the optimum seeding dates and rates.
- To determine which weeds become problems in winter wheat, design control strategies and assess tolerance of new varieties to herbicides.
- To quantify the impact of disease on winter wheat productivity.

This project will provide farmers in the western parkland region with a flexible agronomic package for producing quality winter wheat at low risk.

For more information on the winter wheat in the south, contact Dr. Ross McKenzie at 381-5126.

For more information on the winter wheat project in the western parkland, contact Dan Heaney at 427-7098.

How Do Herbicides Really Work?

Confused about herbicides? *How Herbicides Work*, a new publication written by Dr. Linda Hall, Agronomy Unit, AAFRD explains how herbicides work, how they enter and move in the plant, how they breakdown in the plant and soil, and how they are affected by water quality and spray volume. The book includes details on the four major groups of herbicides as well as general principles of herbicide action. Color diagrams and photographs of herbicide symptoms make this book easy to understand. *How Herbicides Work* will be available in the fall from the Publication Branch for a cost of $25.00. For more information, phone 1-800-292-5697.

Need more? The Agronomy Unit, in conjunction with the University of Alberta's Department of Extension and Department of Agricultural, Food and Nutritional Science, is offering a course on *How Herbicides Work*. This four day course will provide hands-on experience with herbicide symptoms in weeds and crop plants. The final day will be a research update, where weed scientists from across the prairies describe what's new in herbicide and weed research. The course will run February 18-21 at a cost of $600 for both the course and update, $500, if 10 or more are registered at the same time and $100 for just the update (includes a lunch).

For more information, phone Trish Heron at 427-7098 or (fax) 422-9745.

AFFIRM Ready For Release

Len Kryzanowski,
Crop Nutrition Agronomist,
Agronomy Unit

The Alberta Farm Fertilizer Information and Recommendation Manager (AFFIRM) software is ready for use by producers, crop specialists and fertilizer industry agents. Optimizing fertilizer requirements for crop production are influenced by many soil, crop, climatic and management factors. The interaction of these factors can be complex.

AFFIRM will allow the user to evaluate fertilizer requirements for crop production based on Alberta research and production economics. Information specific to the user's situation is entered into this decision support system to obtain a fertilizer recommendation and/or to test various cropping scenarios. Based on the results of these scenarios, the user can make a final decision on fertilizer requirements.

AFFIRM is an interactive user-friendly system that allows the user to select a crop to be grown, identify the field's agro-climatic region, input soil and crop management practices and enter soil test results from a laboratory report into the model. In addition, the model requires values for fertilizer costs and an expected grain value. The model is designed to access a series of small databases to retrieve various coefficients based on the information entered by the user. These coefficients are then used in a series of calculations designed to generate N, P_2O_5, K_2O, S and micronutrient fertilizer requirements and crop yield response to incremental rates of fertilizer for the major crops and agro-climatic zones in Alberta. The yield response model uses a set of empirical equations for dryland and irrigated crops. These equations utilize soil test nitrogen, incremental fertilizer nitrogen rates, spring soil moisture and expected growing season precipitation based on long-term normals for the region. The predicted crop yield response plus fertilizer cost and expected crop value is used to estimate the economic return from fertilizer use.

AFFIRM is a full spectrum fertilizer recommendation system for N, P, K, S plus micronutrients. It will accept soil test results from a variety of laboratories that use various soil test procedures. *AFFIRM* uses unique calibration functions fOr each soil test method. *AFFIRM* provides an economic analysis based on marginal revenue vs. marginal cost for each 10 pound/acre increment of fertilizer nitrogen. It demonstrates the economic relationship that marginal revenue product must be greater than marginal factor cost for an input to remain economic at a given use level. The producer is told how much he is expected to make from each dollar he spends on fertilizer and how this will change if he spends an extra dollar on nitrogen fertilizer (or cuts back by a dollar).

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Thinking about fall fertilizing? Read this first!

Rules of thumb for nitrogen application methods and timing:

- Generally, in terms of fertilizer use efficiency, spring banding is the most effective method of N application and fall banding is the least effective.
- Fall banding is as effective as spring banding N, if there is no extended periods of saturation in the spring.
- Fall banding N may be more effective than spring banding when lack of seedbed moisture is a concern.

Tips to consider before you fertilize this fall:

- Soil test to determined optimal rates of fertilizer.
- Apply a conservative rate, say 75% of soil test recommendation. If conditions are favorable next spring, additional N can be applied with the seed.
- Select a fertilizer formulation that is right for your area.
  Under low risk conditions, anhydrous ammonia, urea, ammonium nitrate or liquid urea-ammonia nitrate perform equally well when banded. Under high pH soils, losses through ammonia volatilization can occur if bands are too shallow or the soil is dry and cloddy.
  Avoid the use of nitrate fertilizers on soils that tend to be saturated in the spring. Nitrates are subject to both denitrification and leaching losses under wet spring conditions.
- Apply N late in the fall after the soil temperature has dropped below 7^{o} C.
- Band, don't broadcast. Banding restricts the contact between fertilizer and soil and as a result overwinter losses are reduced.

Other management factors to consider:

- Fall fertilization can improve your time management.
- Fertilizer prices and payment schedules tend to be more favorable in the fall.
- Availability of product and equipment is often better in the fall.

AFFIRM will give producers, private consultants, fertilizer dealers and field staff a tool to increase their knowledge and skills in fertilizer use for crop production. The inclusion of marginal economic concepts in the model makes it unique from other models used by the fertilizer/soil testing industry. Other fertilizer recommendation software ask the producer for a target yield and then determine how much fertilizer to apply to get that yield. When asked for a target, a producer doesn't want to plan for a low or even average yield. He generally targets the highest yield which often is too high in economic terms. This causes the fertilizer recommendation to be too high. Consequently he gets less than a dollar back for his last dollar investment in fertilizer. Conversely, a very low target yield will prevent a producer from achieving the maximum potential return from his fertilizer investment. The target yield approach is much simpler to explain to a producer but does not identify the associated risks and benefits that can be demonstrated using the yield response approach.

AFFIRM was developed by a team of agronomic production and economic specialists from Alberta Agriculture, Food and Rural Development. The team included Len Kryzanowski, Dr. Ross McKenzie, Frank Jetter and Ted Ford. It was developed with financial assistance from PARI-DSS. The current version will run on any system that meets the minimum system requirements for Microsoft Windows 3.1 or Windows 95. A minimum of 4.5 MB free hard disk space is required.

AFFIRM software will encourage producers to make fertilizer use decisions based on economic principles. For producers who tend to use excessive amounts of fertilizers, this could improve their income by reducing their average production costs. For producers who use very low rates of fertilizer, *AFFIRM* will demonstrate the economic benefits of optimum fertilizer application to increase farm income. For some producers, *AFFIRM* may provide lower recommended fertilizer rates than software based on target yields. This will optimize the amount of fertilizer nutrients, reduce the potential for negative environmental impact from leaching and runoff, and conserve fertilizer resources. *AFFIRM* provides a means of understanding the impact of soil moisture conservation on crop production and fertilizer requirements.

For more information, contact Len Kryzanowski at 427-6361.

You be the diagnostician!

A farmer from the Neerlandia area comes to you with a concern about his barley. His suspicion, tank carryover. The most obvious symptom was small irregular patches of lodging barley occurring a field that until this year was under forage. Other symptoms included reduced growth and thin kernels within those patches. You ask a few more questions and this is the additional information provided:

- barley variety – 2 row Manley.
- soil texture – loamy sand.
- herbicide used – Refine Extra at recommended rate and timing, previous tank was Poast/Muster.
- black shiny lesions on the roots and crown.
- patches were of no particular size and had no particular pattern in the field.
- small sooty black lesions on the head, stem and leaves.

Diagnosis:

First thing, you can reassure the farmer, it is not tank carryover. Damage at the beginning of the field as the offending herbicide is sprayed out is very characteristic of tank carryover. Random patches throughout a field is not a characteristic pattern.

The small sooty black spots on the head, leaves and stems are caused by a saprophytic fungi that moves in after the plants die back. They are of no consequence.

Of particular interest, are the shiny black lesions on roots and crown. This symptom is very characteristic of Take-all (*Gaeumannomyces graminis*). We usually think of Take-all as a disease of wheat. But, it also can infect barley, rye, brome and quackgrass. Affected plants may occur singly or in patches throughout the field. Lodging of the crop may become a problem. The fungus overwinters in grasses and residue from infected plants. Cool, moist springs increase the levels of infection.

Take-all may have been present in the grass component of his pasture and with this year's very cool, wet conditions, may have moved into the barley.

Another factor that points to Take-all, is the sandy texture of his soil. Coarse textured soils are prone to being copper deficient. In fact, several fields in the Neerlandia area have been diagnosed with copper deficiency. The incidence of diseases such as, ergot, Take-all, and Take-all like symptoms, tend to increase in areas of copper deficiency.

To confirm your diagnosis, you could: send plant samples to the Brooks Diagnostic Laboratory (fee for service) or to the Provincial Plant Pathologist to identify the causal agent. Take soil samples at 0-6, 6-12 and 12-24 inch increments from both the affected and non-affected areas. Have them analyzed for copper to see if, in fact, low copper levels are exaggerating the Take-all problem.

Meet the Specialist

Len M. Kryzanowski, Crop Nutrition Agronomist, Agronomy Unit

Len was born in Viking, Alberta and raised on a livestock and grain mixed farm north of Viking. It was there that his interest in the science of plant growth first began. "Shovelling pig manure every Saturday morning really turned me off animal science". Len graduated from the University of Alberta with a B.Sc. in Agronomy in 1977. It was during his summer employment with Agriculture Canada at Lethbridge that he became interested in soil fertility and crop production.

In 1982, Len completed his M.Sc. in Soil Science with Dr. Jim Robertson. His thesis work concentrated on crop response to phosphate fertilizer and the influence of soil properties. This was also where he developed his skills with computers, data analysis and generating enormous computer printouts. This skill lead to his first position with the Soils Branch, Alberta Agriculture in 1980. He would later become a permanent employee with the Alberta Agriculture Soil & Feed Testing Laboratory. Len was part of a team of soil specialists who provided fertilizer recommendations plus soil and crop diagnostics. Now as part of the Agronomy Unit, he has become more involved with field research but still provides diagnostic interpretation of soil test results. His research activites include:

- Making the most of nitrogen
- Fertilizer requirements of irrigated grains & oilseed crops in Southern Alberta
- Nutrient management of irrigated alfalfa
- Field evaluation of laboratory tests for soil phosphorus
- Dryland farming system research for southern Alberta
- Fertilizer management of forage crops
- Geographic management of agronomic and conservation practices using the EPIC model
- Crop growth model for spring barley using the CERES model
- *AFFIRM* (Alberta Farm Fertilizer Information and Recommendation Manager) software

In the past couple of years, Len has been focusing on soil and crop models for landscape management of fertilizer application for precision farming as part of his Ph.D. work at the U of A. "We now have the technological ability to precisely locate ourselves in a field, but what do we do once were there? Precision farming has an enormous potential for optimizing crop production and minimizing environmental impact of agricultural practices. However, a number of questions regarding the measurement and management of landscape variability need to addressed to provide a reliable basis for varying agronomic practices in a field".

Len's other related work include the Alberta Soil Science Workshop, Canadian Soil Science Society, Project Barley Internet Team, Alberta Soil Fertility Committee, and the Plant Industry Division Information Technology Committee.

Outside of his professional life, Len has been very active as a volunteer in Edmonton. This includes coordinating the mainstage security of the Edmonton Folk Music Festival, co-coordinator of the United Way campaign for Alberta Agriculture, a volunteer for the Universiade Games and various security activities for the Fringe theatre festival.

Quorn Mycoprotein

Quorn – what is it? Quorn is a non-animal (fungal) protein made from a non-pathogenic race of the usually destructive fungus, Fusarium graminearum (the commonly pathogenic forms of this species are the causal agents of head blight in barley and oats, and tombstone in wheat.) Mass production and increasing retail sales of this $10/pound meat substitute are occurring in the U.K. Products currently widely available in the U.K. include: Quorn burgers, Quorn sausages, various pies and pasties, and a range of other pre-cooked convenience foods. Quorn is sold in minced or chunk form, and is most commonly used as a substitute for recipes where beef or chicken are normally recommended. It is popular with vegatarians and the health-conscious, and the recent beef-scare in the U.K. undoubtedly stimulated Quorn sales further still.

More in the next issue of **Soil***utions*.

Gregory Wolff

Dear Aggie,

What causes tank contamination problems?

Stuck on You

Dear Stuck,

Tank contamination is caused by herbicide sticking to the inside of spray tanks, lines and nozzles. The Group 2 herbicides tend to be particularly bad for this. This group of herbicides includes Ally, Refine Extra, Amber and the pre-mixes they are included in, such as Triumph Plus and Champion Plus. When another herbicide is used with a super surfactant (Turbocharge, Merge, or Amigo) or the spray solution sits overnight, these herbicides can be scoured out of the tank and damage the next crop that is sprayed. These herbicides are damaging on peas, canola and special crops. Symptoms include stunting, shortening, destruction of the growing point, reddening and chlorosis. Finish or other ammonia based tank cleaners should be used to remove these carry over herbicides, but it must be allowed sufficient time for the cleaner to break down the herbicide. How much time? Overnight is best!

Dear Aggie,

I am growing potatoes on a field scale. Within one of the crops there is a small patch of potatoes which are showing signs of damage; stunted growth, yellowing, and some spotting on the leaves. The previous crop grown on this area was peas. What could be causing the damage?

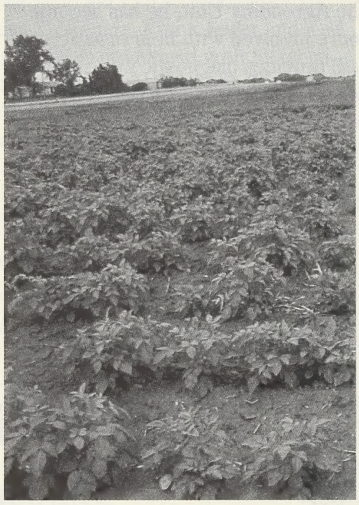
Tiny Taters

Dear Tiny,

When diagnosing a crop growth problem, many factors should be taken into consideration: environmental conditions, soil type, distribution of symptoms, crop rotation, fertility and herbicide regime.

Could the problem be caused by:

Nutrient deficiency? Nutrient deficiencies such as nitrogen and sulphur can cause yellow discoloration. Before ruling out a deficiency problem; soil sample the affected and unaffected areas, review past cropping and fertilizer practices.



Insect damage? Field scouting can give you a good indication as to whether or not insect damage is causing the symptoms.

Disease? Some diseases can become a problem if the rotation between certain crops is not long enough.

Herbicide residue/drift/tank contamination? The symptoms seem to be isolated to the area previously cropped to peas. If the peas were sprayed with the herbicide, Pursuit, you may have a residue problem when growing potatoes the following year. Pursuit is not registered for use on potatoes and potatoes are not listed as a recommended crop to be grown in the year following application. Pursuit is absorbed by the roots as well as the foliage, therefore residue in the soil can affect the following crop. Pursuit stops growth by disrupting the metabolism of the plant, causing symptoms such as stunted growth and damage to the youngest leaves and growing point. Leaves can take on a yellow, purple or reddish discoloration and begin to die. Damage caused by herbicide residue may vary in severity therefore death of the plant may not occur.

Drift and tank contamination can cause the same symptoms as a residue problem. Eliminating these as the cause can be done by reviewing this year's spraying regime and looking at the pattern of the damage.

Keeping thorough crop management records means that available information makes crop diagnosis easier.

You can write to:
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